# Modeling of the Disc Speed

Nur Huda Mohd Amin, Hyreil Anuar Kasdirin, and Mohd Ruddin Ab. Ghani
Faculty of Electrical Engineering
Universiti Teknikal Malaysia Melaka
Melaka, Malaysia
nurhudama@gmail.com

***Abstract-*** **This paper presented the modeling of the disc speed. The analysis and design of control systems for the modeling is assigned in leading computer solutions and linearizing nonlinear systems.**

***Keywords:*** *modeling, rotational motion, disc speed*

## I. Introduction

One of the most important tasks in the analysis and design of control systems is Mathematical modeling of the systems. In the preceding chapter, we have introduced two most common methods of modeling linear systems namely the transfer function method and the state-variable method. The transfer function is valid only for linear time-invariant systems, whereas the state equations can be applied to linear as well as nonlinear systems.

Although the analysis and design of linear control systems have been well developed, their counterparts for non-linear systems are usually quite complex. Therefore, the control systems engineer often has the task of determining not only how to accurately describe a system mathematically, but, more important, how to make proper assumptions and approximations.

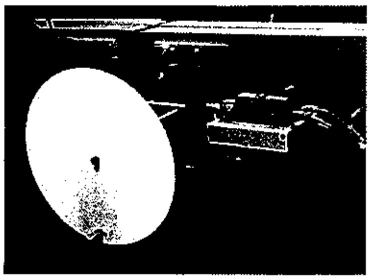

Fig.1: Rotational disc plant

Fig.1 illustrates the proposed set up of rotational disc plant which will be conducted in this project. This proposed set up consist motor and robot driver will be integrated with the MATLAB software for development of control algorithm. The sensors in the plant will be made as its feedback to the main controller at which, the PI control systems of feedback control mechanism will be designed and developed for this project.

Moreover, this disc speed might determine from the open-loop model control of system recognition based on real-time that is related to the MATLAB system identification and represented in block diagram as shown in Fig.2. From Brennan, Fletcher, and Norrie's [4] point of view, current industrial control is typically implemented using large and expensive hardware platforms. This implementation encourages Brennan, Fletcher, and Norrie's to develop system by using real-time. Speed of the disc is also applied in the simulation. The output response that is produced from the MATLAB/Simulink model will be discussed later in system analysis section.

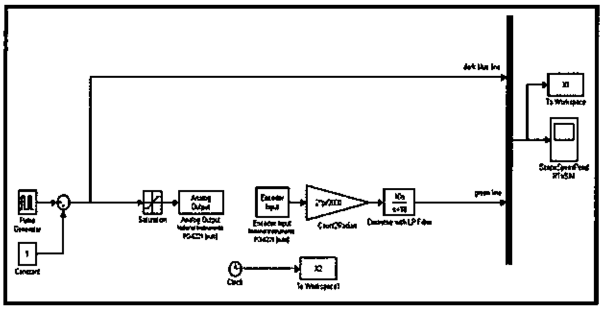

Fig.2: Model for open loop system of disc speed

The model for open loop system of speed is built with real-time and run to reconfirm these simulink models no error. These running simulink models give variables X1 and X2 in the Workspace of the MATLAB. (Note: Analog Output; encoder1/channel 1 and term X1 and X2 could be defined for any of alphabetical words from A to Z).

## II. Experimental Designs

According to Meriam and Kraige [5], when the earth rotates, the acceleration of a freely falling body as measured from a position attached to the surface of the earth is slightly less than the absolute value. The lab experimental tests might prove the acceleration of a freely falling body gives impact to the disc rotating. This impact could be improved for better with system design. System design applied rotational disc and dc servomotor models development at which helpful and useful to get the best response of stability. This sub-section also covers the controller design.

*A. DC servomotor circuit with load of rotational disc and transfer function equation*

Based on the understanding of the DC servomotor circuit [6], the transfer function that describe the position of DC motor is derived as following:

$$\frac{\theta(s)}{E(s)} = \frac{K_t}{s\,[(L_a s + R_a)(Js + B) + K_b K_t]} \quad (1)$$

where $\theta(s)$ referring to the position angle from disc and $E(s)$ referring to voltage gives to DC servomotor.

Tab.1 describes the parameter used in the equation of position DC servomotor:

Table 1: Parameters of DC servomotor and load

| Physical quantity | Symbol (SI unit) | Measurement Values |
|---|---|---|
| armature inductance | $L_a$ (H) | $0.20 \times 10^{-3}$ |
| armature resistance | $R_a$ ($\Omega$) | 1.11 |
| back-emf constant | $K_b$ (Vs/rad) | $36.4 \times 10^{-3}$ |
| torque constant | $K_t$ (Nm/A) | $36.4 \times 10^{-3}$ |
| viscous-friction coefficient | B or $D_1$ (Nms/rad) | $5.469 \times 10^{-3}$ |
| rotor inertia | $J_1$ ($kgm^2$) | $6.77 \times 10^{-6}$ |
| load inertia | $J_2$ ($kgm^2$) | $2.132 \times 10^{-3}$ |
| total inertia | J ($kgm^2$) | $2.139 \times 10^{-3}$ |

*B. Controllers Designation*

Both model for this research plant system is not completed without controllers design. The designation might consider with conventional control for dynamic systems which refers to Proportional-Integral-Derivative (PID) control, classical control, state-space methods, optimal control, robust control, nonlinear methods, adaptive control, stochastic control and discrete event systems [7]. This open and closed-loop system applied conventional control which is PID control, classical control like Bode and Nyquist methods or root-locus design, and state-space methods like state feedback. Consequently, Proportional and Integral (PI) is designed to get the smooth signals and comparison stability system study (henceforth PD and PID).

*PI Controller*

This controller is built and designed by applying the MATLAB root locus either with analysis response to step command or other loop responses like automatic tuning of PID tuning design method. More details for PI controller is elaborated as on theoretical.

Based on control theoretical study, PD controller may not fulfill the compensation objectives. In that case, the integral part of the PID controller is considerably. The PI controller can retransform in transfer function, $G_c(s) = K_P + (K_I/s)$ [8]. and derived in block diagram as shown on Fig.3. Generally, PD, PI and PID controllers differentiate by their gains.

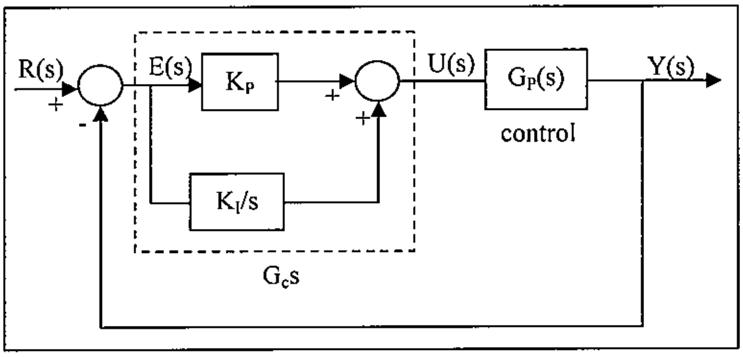


Fig.3: Control system with PI control (adapted from Golnaragi )

## III. Results And Discussion

*System analysis of graphical response*

Model and controllers designing in MATLAB simulink produced results to analyze graphical response. These graphical responses considered open-loop, closed-loop, and also real-time and simulation comparison for open and closed-loop system. The speed and position of disc for the open-loop and closed-loop system are the element to analyze in the graphical response of the lab testing.

Open-loop refers to the system with basic construction and ease of maintenance. This basic construction and ease of maintenance make the open-loop system inexpensive (less expensive than corresponding closed-loop system)[9]. From the graphical response , this open-loop system does not have any problem with the stability as the system operates on time basis[9]. Even though the open-loop operates on time basis, its system cannot compensate for any disturbances that add to the controllers, means the system do not correct disturbance.

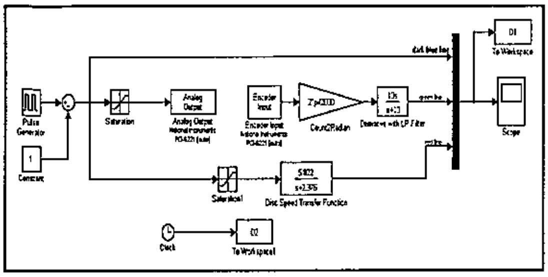

Fig.4: Disc speed model of open-loop system for simulation and real-time comparison

From disc speed model as shown on Fig.4, the input and output responses sorted following signal to Fig.5. This signal shows the performance speed of the open-loop system for comparing the real-time and simulation characteristics. The speed input refer to the square signal that supposed to be reference between simulation and real-time characteristics. Signal produced by real-time gives the highest speed compared others. This simulation and real-time characteristic proved that open-loop system do not correct disturbance [10] and give different output. Disturbances and changes in calibration cause errors where the output may be different from what is desired. Thus, to maintain the required quality in the output, recalibration [10] is necessary from time to time.

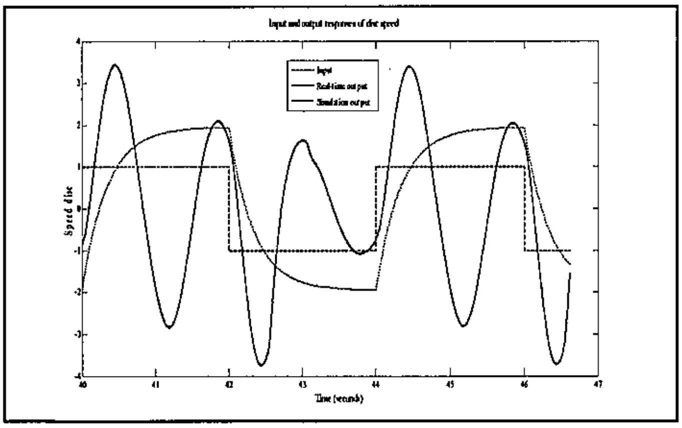

Fig.5: Speed disc signal comparison between real-time and simulation of the open-loop system

Besides, this signal also determined that the real-time give a short period of time but the simulation give a quite long time to operate the system. This open-loop signal could be improved by implementing the closed-loop system.

Fig.6 shows disc speed model of closed-loop system. This closed-loop system produced signal as coded in MATLAB Command Window as shown on Fig.7.

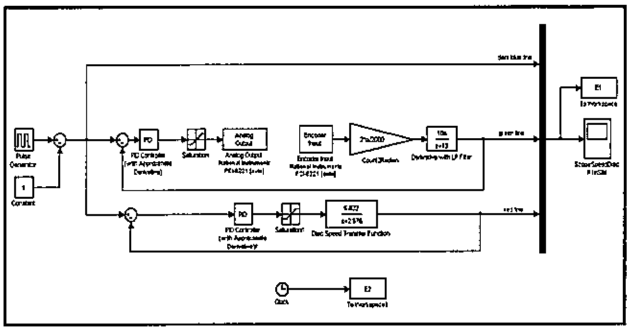

Fig. 6: Disc speed model of closed-loop system for simulation and real-time comparison

From Fig.7, speed disc signal produced by real-time correct disturbance from feedback loop of the closed-loop system that gives output similar to input. Its loop implies the use of feedback control action in order to reduce system error where by the response is compared to the input at the summing junction [10]. Filter added through the model by using real-time, decreased the signal from the input generated. This disc speed model of closed-loop system used PI controller. The PI controller gives effect to the speed disc signal. Based on experimental test done, root locus design presents a small gain of integral that proved the effective [10] and acceptable [11] performance of PI controller. Following from Selvaraj's and Rahim's [12] points, PI controller have high dynamic performance under rapidly changing atmospheric conditions and maintain the power factor at near unity.

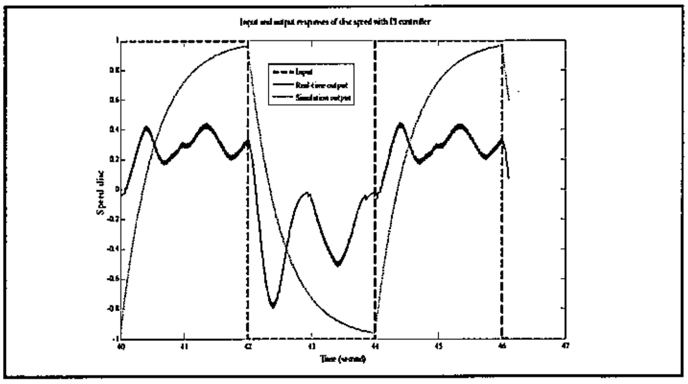

Fig.7: Speed disc signal comparison between real-time and simulation of the closed-loop system

Moreover the graphical response from the closed-loop system produced signal that give less sensitive to noise, disturbances, and changes in the environment. In addition, the transient response and steady-state error appear from the system can be controlled conveniently. Thus, with greater flexibility[10], a simple gain (amplification) in the loop is adjusting and the controller is redesigning.

## IV. Conclusion

The development of control system for this rotational disc might clarify one or more controller used. This paper concludes the open and closed-loop system as well as extended the closed-loop with PI controller for comparison stability between simulation and real-time operation mode. From theoretical understanding, a few experimental tests have break out the comparison stability of control system. The stability of control system depends on performance produced from output response of the open and closed-loop control model.

## Acknowledgement

We would like to express our most gratitude and acknowledgement to the supervisor and researchers from the Faculty of Electrical Engineering, UTeM for their guidance and continuous effort as well as motivation throughout the project. Furthermore, we would like acknowledgement to Universiti Teknikal Malaysia Melaka (UTeM), for their financial support.

## References

[1] C. Jong-Woo and L. Sang-Cheol, "Antiwindup Strategy for PI-Type Speed Controller," *Industrial Electronics, IEEE Transactions on,* vol. 56, pp. 2039-2046, 2009.

[2] A. Vyas and A. K. Bajaj, "Global Dynamics of an Autoparametric System With Multiple Pendulums," *J. Comput. Nonlinear Dynam.* , vol. 1, p. 35, 2006.

[3] T. Samad, *Perspectives in Control Engineering.* New York: IEEE PRESS, 2001.

[4] R. W. Brennan, M. Fletcher, and D. H. Norrie, "An agent-based approach to reconfiguration of real-time distributed control systems," *Robotics and Automation, IEEE Transactions on,* vol. 18, pp. 444-451, 2002.

[5] J. L. Meriam and L. G. Kraige, *Engineering Mechanics Dynamics* vol. 2: John Wiley & Sons Inc, 2007.

[6] B. C.Kuo and F. Golnaraghi, *Automatic Control Systems*, 8 ed.: John Wiley & Sons Inc, 2003.

[7] K. M.Passino and S. Yurkovich, *Fuzzy Control*: Addison Wesley, 1998.

[8] B. C.Kuo and F. Golnaraghi, *Automatic Control Systems*, 8 ed.: John Wiley & Sons Inc, 2003.

[9] K. Ogata, *Modern Control Engineering*, Fourth ed. New Jersey: Prentice Hall, 2002.

[10] N. S.Nise, *Control Systems Engineering*, Fifth Edition ed.: John Wiley & Sons, Inc, 2008.

[11] G. C.Goodwin, S. F.Graebe, and M. E.Salgado, *Control System Design*, 2000.

[12] J. Selvaraj and N. A. Rahim, "Multilevel Inverter For Grid-Connected PV System Employing Digital PI Controller," *Industrial Electronics, IEEE Transactions on,* vol. 56, pp. 149-158, 2009.